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Drying Simulation of Pumpkin Seed

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Abstract **-**In this study, moisture distribution of coarse type pumpkin seed in the form of spheroid is modelled by using diffusion equation. The analysis made for natural sun drying for constant environment temperature. Simulation results were obtained by Comsol Multiphysics finite element analysis software for 0.5, 1, 2, 5, 10, 15, 20, 25, 30 and 34 hours respectively. On the other hand, average moisture content as a function of time is obtained and an exponential decay type cure with three parameters is fitted to these results. The results show that drying rate of pumpkin seed is falling with time. Simulations shows a good agreement with experimental results at the literature.

Keywords**:** Drying, pumpkin seed, diffusion

1. Introduction

Drying is one of the common preservation techniques of food stuff. During drying process not only product quality but also energy economy should be taken into account. On the other hand drying phenomena and mass transfer mechanisms of drying is an attractive subject for other industries such as textile industry and drug industry. Scientists have been trying to explain the mass transfer mechanisms and it has been observed that liquid diffusion is generally sufficient to explain of drying of food stuff.

Generally drying of hygroscopic materials takes place in two or three stages. First stage is called as constant rate stage, second and third stages are falling rate stages. At the end of the first stage of drying, drying rate starts to decrease, because it takes time for moisture to reach to surface of the material where evaporation occurs. In this study drying behaviour of pumpkin seed is modelled by diffusion equation. Pumpkin seed is generally dryed by natural convection, called as open sun drying, and force convection, called as hot air drying. Sacilik (2007) dryied hull-less pumking seed by using the methods of hot air, solar tunnel and open sun drying respectively. He used Fick's diffusion model for modelling moisture transfer inside the pumpkin seed, calculated effective diffusion coefficients for each drying method and presented Arrhenius-type effective diffusion coefficient as a function of temperature. He applied experimental results to some of known models and determined related coefficients. Guiné et al. (2011) dried pumpkin by forced convection inside a drying chamber. They obtained moisture ratio as a function of time. Results show that drying air temperature has a strong effect on drying time, that is while drying takes 8h at 30^oC, increasing temperature to from 30^oC to 70^oC it only takes 2h. They also show that Page model is the convenient model for their results among examined other models. Tunde-Akintunde and Ogunlakin (2011) studied drying of thin-layer pretreated and untreated pumpkin using hot air dryer. They determined effective moisture diffusion coefficients for each conditions they examined. Kavak Akpınar and Biçer (2008) experimentally investigated thin layer drying characteristics of long gren pepper under the effect of forced convection and natural convection respectively. In their study it has been shown that while logarithmic model is the best convenient model for forced convection drying, Midilli and Kucuk model is the best one for natural convection. Hashim et.al. (2014) made an experimental study on drying of pumpkin using a hot air convective dryer. They dried samples of pumkin at 50 °C, 60 °C and 70 °C. Their results show that Lewis, Henderson and Pabis models are the best convenient models, but Page model is not.

2. Material and Method

Simulations of moisture distribution inside the coarse type pumpkin seed, exposed to open sun drying, is investigated by Comsol Multiphysics finite element analysis software. Dimensions of 20 coarse type pumpkin seed are measured. Average measurements were taken as the measurements of the pumpkin seed examined. The values of semiaxes are 11.32 mm, 6.57 mm and 1.59 mm.

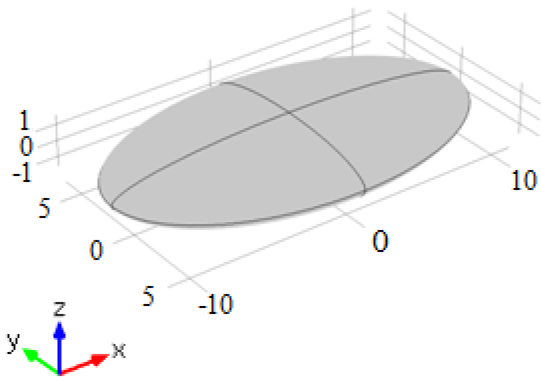

Fig. 1. Pumpkin seed

The governing equation is diffusion equation. The values of initial and equilibrium moisture contents and the convenient diffusion equation for open sun drying is taken from the study of Sacilik (2007) and given as follows. It should be noted that environmental temperature is varying between the temperarutes of 10 and 50°C. It also makes a peak during the day.

$$\vec{\nabla} \cdot \left(D_{eff} \vec{\nabla} X \right) = \frac{\partial X}{\partial t} \tag{1}$$

$$D_{eff} = 1.66 \cdot 10^{-11} \tag{2}$$

$$X_o = 0.67 \tag{3}$$

$$X_e = 0.06 \tag{4}$$

When defining boundary conditions it is assumed that surface of the pumpkin seed is in equilibrium moisture content. Convenient boundary and initial conditions are defined as given in Eq. 4. and 5. respectively.

$$X|_s = X_e \tag{4}$$

$$X|_{t=0} = X_o \tag{5}$$

4. Conclusion

As moisture distribution inside the food stuff principally affects the product quality, simulation results based on diffusion equation are obtained and the results for 0.5h, 1h, 2h, 5h, 10h, 15h, 20h, 25h, 30h and

34h are presented. It should be noted that drying starts from the surface, outer region of the pumpkin seed reaches to equilibrium moisture content first with respect to the inner region.

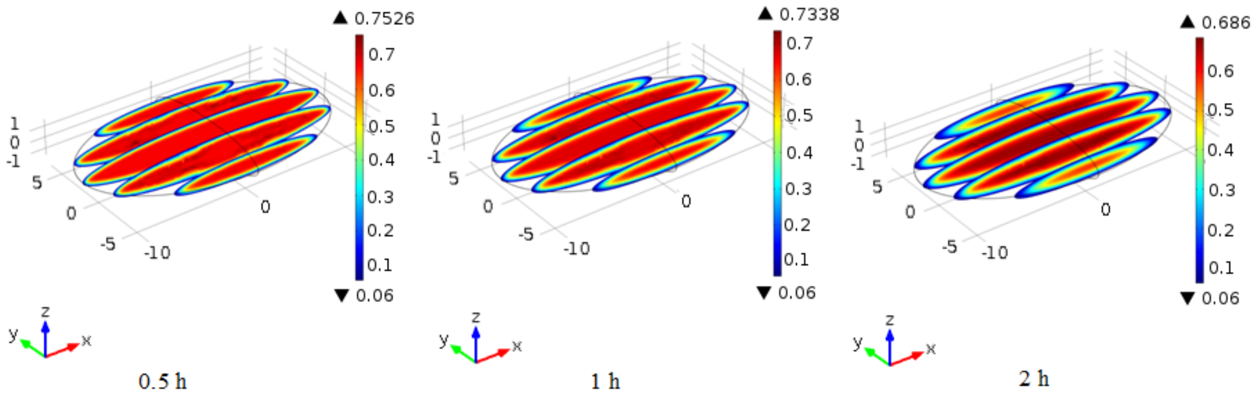

Fig. 2. Moisture distribution inside the pumpkin seed at 0.5h, 1h and 2h

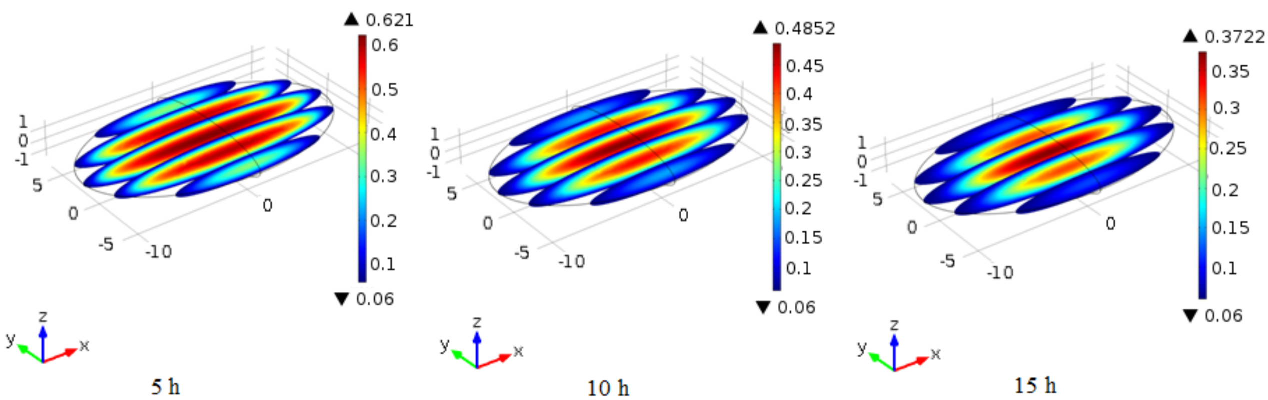

Fig. 3. Moisture distribution inside the pumpkin seed at 5h, 10h and 20h

On the other hand average moisture content as a function of time is obtained and this shows good agreement with the experimental results in the study made by Sacilik (2007). In order to compare results of this study with the results of Sacilik (2007), obtained values after 34h are not given in this paper. It has been shown that drying of pumpkin seed is in the falling rate period. Drying phenomena is modelled by diffusion, drying rate is proportional to the moisture gradient. As time proceeds moisture gradient decreases, accordingly drying rate is.

As pumpkin seeds are naturally dryed, it takes 34h for the pumpkin seed to reach approximately moisture content of 0.1 (d.b.). Finally according to the results drying of pumpkin seed can be modelled by an exponential decay, 3 parameter curve given as Eq. 6. where time is in seconds.

$$X = 0.0813+0.4716 \exp(-0.1231*t) \tag{6}$$

Nomenclature

D_{eff}: Efffective diffusion coefficient (m^2/s)
t: Time (s)
X_e (d.b.): Equilibrium moisture content
X_o (d.b.): Initial moisture content

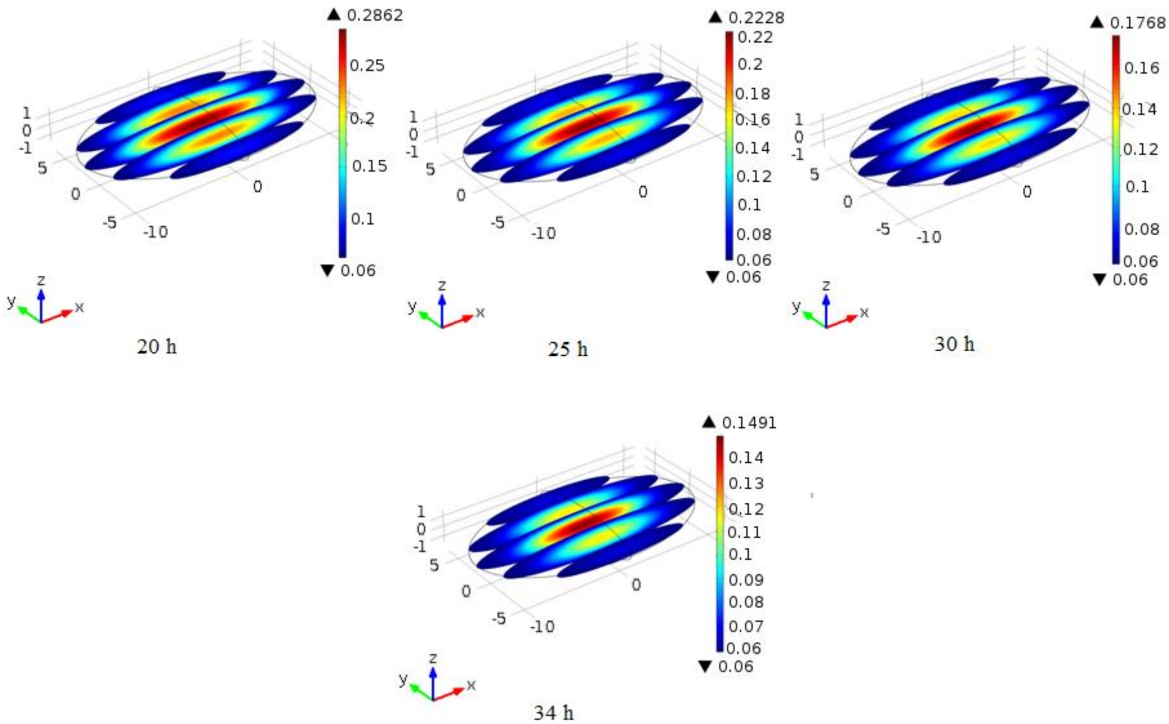

Fig. 4. Moisture distribution inside the pumpkin seed at 20h, 25h, 30h and 34h

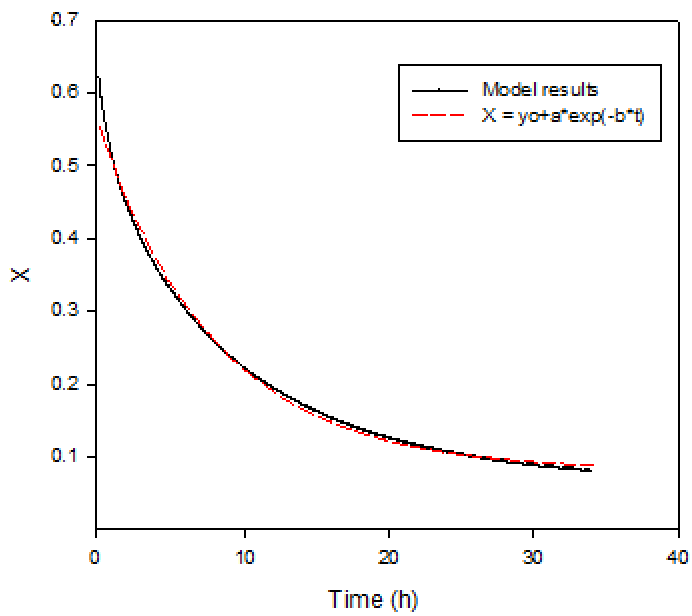

Fig. 5. Average moisture content of pumpkin seed

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